1. INTRODUCTION

The bitumen-rubber technology was brought to the attention of Sastech and Tosas in May 1981 during discussions with the Arizona Department of Transport in Phoenix, Arizona. Confidential discussions were held with the Transvaal Roads Department and the Department of Land Transport. The object of these discussions were to ascertain from these road authorities if this technology had a place in South Africa. The reaction was positive with the comment that "provided the product had a good road performance history over a reasonable period of time" it would be acceptable and would be judged on its performance on South African roads.

A final meeting was held at the NITRR. The enthusiasm of the NITRR officials was instrumental in the final decision to purchase the exclusive rights for the Arizona Refining bitumen-rubber technology.

2. ARIZONA REFINING'S (ARCO) CONCEPT OF BITUMEN-RUBBER BINDERS(1)

2.1 South Africa Blend Components

Prior to finalising the license for this technology, samples of the blend components were sent to ARCO for testing and evaluation.

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The conclusions from this work was that we could produce an excellent bitumen-rubber with this technology in South Africa.

To date we have followed the Arizona Refining modus operandi (which incidently forms part of the licensing agreement) to the letter with very good results in practice on the road.

2.2 Blending of bitumen-rubber

Correctly and properly blended bitumen-rubber can provide a product with the following properties, namely:

- greater flexibility at low temperature,
- resistance to hot weather problems,
- better viscosity, and
- longer durability than normal bitumen.

Bitumen-rubber is a unique material although used in the same applications as bitumen, and "engineers should avoid the pitfall of regarding it as a modified bitumen". ARCO approach the production of their material in the same way as an adhesive manufacturer, namely, careful process design and the selection of a group of raw materials specifically chosen to add each of the desireable properties rather than indiscriminately adding scrap rubber to bitumen.

2.3 Bitumen-rubber Reaction

Previous work by Morris & McDonald\(^{(2)}\) has shown that when ground rubber is soaked in an aromatic oil similar to that found as a component in bitumen, it swells substantially producing a dramatic increase in the viscosity of the mixture.

The same effect is observed when rubber is combined with bitumen at high temperatures of 177 - 205°C.
Figure 1 shows the effect of adding rubber and the influence of prolonged heating on viscosity.

ARCO react the blend to a viscosity suitable for use in conventional spray equipment. This produces a product with good flexibility, elasticity and adhesion while maintaining high temperature properties that are better than conventional bitumen.

The combination of the rubber with the oil is complex but it appears to produce three phases as shown in Figure 2, namely, unreacted rubber particle, gel and oil.

Further reaction is shown in Figure 3, the rubber is progressively converted from a resilient particle to a gel and finally to an oil when the rubber has been totally dispersed.

Each of these phases contributes to the properties of bitumen-rubber. The particle or elastomeric provides resilience, the gel improves the low temperature properties while increasing the softening point and viscosity. The oil phase improves the durability and increases flexibility.

Bitumen-rubber should contain a balance of these three phases to provide all the desirable properties. This is accomplished, firstly, by adding a sufficient quantity of rubber to allow portions of the rubber to be converted to each of the two phases while maintaining a reserve of unreacted and, secondly, by controlling the factors which influence the bitumen-rubber reaction.

2.4 Rubber Properties

The type of hydrocarbon present in the rubber controls the degree and rate of reaction between the rubber crumbs and the hot bitumen.

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The relative reactivity of the various types of rubber found in scrap materials is shown below:

- Natural
- More reactive
- Synthetic (SBR)
- Neoprene

In the ARCO process, rubber that is high in natural rubber content is vulcanised to ensure a greater degree of reaction between the rubber and bitumen at high temperatures. The natural rubber also provides better elasticity and adhesion than synthetic rubber. For this reason a minimum of 30% by mass of the rubber component of the blend must be natural rubber.

2.5 Rubber Morphology

The surface area of a material greatly affects the degrees of chemical reaction. Figure 4 shows the difference when large or small particles of rubber are dispersed in bitumen.

The large particles remain functionally unreacted rubber floating in the bitumen with a small percentage of gel on the surface. The small particles form a large amount of gel so that the compound is a matrix of gel, bitumen and resilient rubber which defies separation.

2.6 Temperature Versus Time

Rubber, oil and bitumen will react slowly at fairly low temperatures. Relatively high temperatures (177 - 205°C) are necessary to provide quick production of bitumen-rubber. The reaction is time dependent and at a high temperature of above 218°C the reaction is so fast that it is impractical to hold the blend without carrying the reaction beyond the desired stage. This was shown in Figure 1 previously.
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2.7 Chemical Properties of Bitumen

Probably the most critical and difficult factor to control is the chemical properties of the bitumen.

ARCO research has shown that the second acidaffins fraction of the bitumen has the greatest effect on the solubility of the crumb rubber.

In addition, this research has shown that the bitumen must be well balanced\(^6\). It must contain the proper quantities of the other components to produce the best blend.

This principle is illustrated in Figure 5. In stage 1, the rubber has been mixed with the bitumen and appears in the asphaltenes fraction as undissolved material. The absorption of the oil is shown by the depletion of the second acidaffin fraction.

In stage 2, the Nitrogen base fraction is increased indicating the conversion of the solid rubber particles to the more soluble gel state.

At stage 3, where the rubber is overreacted, the product is returning to the state similar to the original bitumen with the exception that the second acidaffin have been converted to other fractions.

The paraffin remains relatively unaffected. The slight increase in stages 1 and 2 is probably due to the release of oils from the rubber.

2.8 Effect of Rubber Processing

Various processing methods result in different morphology (structure) of the rubber particles. Oliver\(^3\) showed that the

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FIGURE 5

COMBINATION OF RUBBER WITH BITUMEN FRACTIONS

BUFFINGS - MAINLY SMOOTH FACED PARTICLES
*ELASTIC RECOVERY 21%

AMBIENTLY GROUND - PARTICLE SURFACE COVERED WITH POROUS NODULES
*ELASTIC RECOVERY 35%

CRYOGENICALLY GROUND - SMOOTH FACED ANGULAR CRACKED PARTICLES
*ELASTIC RECOVERY 6%

* John W.H. OLIVER
   Australian Road Research Board
morbidity of the rubber particles was the most important factor affecting elastic recovery.

The process, particle structure, morphology and relative recovery are shown in Figure 6.

3. FULL-SCALE TEST SECTIONS

Following a technology transfer visit to South Africa in October/November 1982 by Don Nielsen (former President of Arizona Refining, a comprehensive full-scale road test programme was embarked upon.

Twenty two full-scale sections were constructed in conjunction with the Transvaal and Cape Roads Departments and also the Department of Land Transport. In most of the cases the bitumen-rubber binder was manufactured, transported and sprayed on site free of charge by Tosas.

4. QUALITY CONTROL

Strict quality control during all phases from the blending operation to the final rolling of the aggregate or the hot premix are essential.

4.1 Check of the Base Bitumen

It is well known that since the 1973 oil crisis, South Africa has been forced to purchase its crude oil on the spot or open market. Consequently crude oil can and does vary resulting in a base bitumen of varying chemical composition in respect of asphaltenes, maltenes, acidaffins and paraffins to name but a few.

For this reason an ongoing check of the blend formulation is monitored as and when crude oil sources of Natref changes. In
respect of the coastal refineries a sample is obtained approximately one to two weeks before the start of a project to ascertain blend proportions.

4.2 Sampling

To-date approximately 3 000 metric tonnes have been supplied to various road authorities and contractors. We have from the very outset endeavoured to sample every batch/distributor load blended.

For every project samples are taken of the base bitumen, the crumb rubber and the final bitumen-rubber blend. These components are then analysed in the laboratory in terms of test methods recommended by a technical sub-committee for testing bitumen-rubber convened by the South African Bitumen and Tar Association. These test results are then fed into a data bank currently being compiled by Tosas.

4.3 Laboratory tests

The following routine standard tests are carried out at Sasol I on samples taken in the field.

**Base bitumen** - Penetration
- Softening point

**Crumb rubber** - Chemical composition
- Grading
- Morphology (bulk density)

**Bitumen-rubber** - Viscosity versus temperature
- Softening point (R & B)
- Standard penetration (Needle)
- Resiliency (Ball)
- Flow
- Elastic recovery (McDonald)
4.4 **Site quality control**

Quality control, on a site where blending takes place, is carried out by a supervisor whose responsibility includes:

- storage of rubber,
- modification of bitumen with oil,
- blending of the bitumen-rubber,
- checking of air and road temperature,
- ensuring that the recommended chipping and rolling techniques are adhered,
- liaison with the main contractor,
- recording of all the required documentation.

5. **CONCLUSIONS**

Approximately two years have elapsed since the first spray application (October 1982) of bitumen-rubber in the RSA and the following conclusions can be made:

- Strict quality control during blending and during site spraying are essential.

- A high standard of supervision is required.

- Careful attention must be paid to road and air temperature during spray applications.

- For spray and chip work the chips must be applied and rolled while the binder is still hot. Failure to ensure this can result in subsequent chip loss.

- Precoated chips appear to result in better adhesion although unprecoated chips have been successfully used on certain test sections where both road and air temperature have been well in excess of 25°C and 20°C respectively.

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REFERENCES


6. NATIONAL TRANSPORT COMMISSION. Contract No NVK 308902, Repair and Resurfacing of Sections of National Route N3 Section 9 between Warden and Villiers.


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ANNEXURE "A"

TOSAS (PTY) LIMITED

SPECIFICATION FOR ARM-R-SHIELD BITUMEN-RUBBER

1. DESCRIPTION

ARM-R-SHIELD is a mixture of bitumen, oil and ground crumb rubber blended together at an elevated temperature in the manner, proportions and sequence herein described.

2. MATERIALS

2.1 Modified Bitumen-Cement

The bitumen, having penetrations at 25°C ranging from 40 to 300 shall be modified by adding and mixing a suitable amount of oil to form a material that is chemically compatible with rubber.

2.2 Rubber

The crumb rubber is manufactured by grinding at ambient temperatures, scrap tyres. The combined granulated rubber shall consist of a minimum of 80 per cent by mass of vulcanized rubber, and shall contain a minimum of 30 per cent of natural rubber by mass. The combined granulated rubber shall have a specific gravity ranging from 1,10 to 1,20 and shall be free of loose fabric, wire and other contaminants. Calcium carbonate or talc may be added to prevent the rubber particles from sticking together, but such addition shall not exceed four (4) per cent by mass of rubber. The granulated rubber particles shall all pass the 1,18 mm screen and a maximum of 10 per cent shall pass the 0,075 mm sieve. No particles shall exceed 6,35 mm in length.

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3. BITUMEN-RUBBER BLEND

The rubber and modified bitumen shall be combined in a ration of 20 per cent, plus or minus 2 per cent rubber, to 80 per cent, plus or minus 2 per cent modified bitumen, by mass of the total blend and reacted for a sufficient time at 205°C plus or minus 13°C and mixed in such a fashion to produce a product with the following properties:

- Viscosity at 205°C .................. 750-2000 centipoise
- Softening point (R & B) (ASTM D-2398) ..... 58°C Minimum
- Flex Temp. (50°C Bend Test Arizona) .... Minus 17°C Maximum
- Flash point, PMCC (ASTM D-93) ............ 232°C Minimum

In the event a delay occurs when the product is ready to be applied, the heat shall be turned off until the job resumes.

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